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REPORT No: EL. 1414

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Farnborough. Hants.

PRELIMINARY REPORT

VISUAL APPROACH AND LANDING AIDS FOR AIRCRAFT. FUNDAMENTAL PROBLEMS ANALYSED BY MEANS OF PERSPECTIVE DIAGRAMS

by

E. S. CALVERT, B.Sc., A.R.C.Sc.I.

Report No.EL.1414

January, 1947.

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Preliminary Report

Visual approach and landing aids for aircraft. A theoretical analysis of some fundamental aspects of the problem by means of perspective diagrams

by

E.S.Calvert, B.Sc., A.R.C.Sc.I.

R.A.E. Ref: EL/G.3232/159

SUMMARY

Various arrangements of the approach and runway lights are analysed using perspective diagrams, i.e. diagrams which show the exact geometrical appearance of the patterns seen by the pilot, and it is shown that in bad visibility the information given to the pilot by existing patterns is both insufficient and ambiguous. Attention is also drawn to the scale effects which are introduced into the runway lighting pattern when different spacings are used by different countries, and it is pointed out that these effects can only be avoided by international standardisation.

As a result of this analysis, a new pattern is proposed for the approach lights consisting of "horizon bars" arranged transversely to the extended centre line of the runway. It is shown that these can be made to indicate both height and range even when only one bar is seen, and it is hoped that this will enable the pilot to make a safe approach by visual means even in poor visibility once he has picked up the lights. In the case of the runway lights, it is suggested that scale effects could be overcome by adding a standardised scale fixing pattern or "contact mat" at the point of touch down.

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1 Introduction

1.1 Installations for the full scale trial of various patterns of approach and runway lights are expensive, and the time taken to obtain results may run into several years. It is therefore desirable that the fundamental requirements be clearly formulated, and that every new pattern be systematically analysed to see whether it meets these requirements, particularly under conditions of restricted visibility. The writer has found that this analysis is facilitated to an extraordinary extent by the use of perspective diagrams, i.e. diagrams which reproduce the exact geometrical pattern which the pilot sees at any given stage of the approach or landing. The object of this report is briefly to present the results of applying this method of analysis to the approach and landing aids, in the hope that these results will prove useful to those engaged on the urgent task of international standardisation.

1.2 Preparations for the full scale trial of the new pattern of approach lights proposed in this report are now in hand, and until these trials have been completed, the question of whether safe landings can in fact be made on this pattern will remain unsettled. However, even if this particular pattern proves to be unsatisfactory, it is submitted that the method of attack on this problem will remain a fruitful one, and should be exploited by all workers in this field in the hope that a solution, if it exists, may be found as soon as possible.

1.3 This report is intended to be read in conjunction with R.A.E. Report No. EL.1413, which explains in detail how perspective diagrams can readily be made. However, for the convenience of readers who already have a knowledge of perspective, Fig.1 from that report has been reproduced as Fig.1 of the present report. This diagram illustrates the terms which are most commonly used in perspective, and is all that such readers will require in order to follow the discussion given below.

2 General requirements for all approach systems

2.1 From his own experiences and the discussions which he has had with others, the writer has come to the conclusion that anyone learning to control a moving vehicle first unconsciously identifies himself with it, and thereafter thinks of it as an extension of himself. In other words, the would-be pilot of an aircraft has to "grow wings". The process of learning then consists in acquiring a chain of conditioned reflexes linking the movements of the controls with the movements of certain significant parts of the outer world. (In the case of an aircraft making an approach, these are the horizon and the runway.) When a pilot has to fly blind in fog, the outer world is blotted out, and movements of the controls result in movements of pointers on dials, and a sustained and conscious effort is required from him in order to interpret them. In these conditions it is impossible for the pilot to regard the aircraft as an extension of himself, and he is forced to take up the mental attitude of a controller located outside the aircraft, and to acquire a new chain of reflexes linked to these pointer movements. When by intensive training he has succeeded in doing this, flying on these pointer movements may be reasonably easy provided he refrains from looking out of the cockpit. If, however, the pilot does look out, and begins to receive impressions from the outer world, then he is likely to revert to his normal mental identification of himself with the aircraft, and will have difficulty in going back to instruments. The first requirement for the visual approach aids is therefore that they shall form a complete system in themselves, so that the pilot can fly on them without having to refer to his instruments any more than he would do in normal day flying. The second requirement is that the indications received from the approach aids shall resemble those received in normal day flying so closely that the pilot can interpret them instantly and instinctively. In other words, the pilot must not be asked to "do sums" in his head during the approach.

3 Pattern seen by pilot during approach

3.1 In view of the second requirement stated above it is necessary to be clear as to the behaviour of the pattern which is significant for judging the approach, i.e. that formed by the runway and the horizon. Let us therefore consider an aircraft approaching the end of a runway at an angle α as shown in Fig.2, and make perspective projections of this pattern on a vertical picture plane arranged at right angles to the vertical plane through the longitudinal axis of the aircraft. Let us also imagine that this aircraft is equipped with an optical sighting device similar to a reflector gunsight, which projects on the picture plane a vertical line which coincides with the direction of flight when the aircraft is flying on a straight path without bank. Then the pattern seen by the pilot when the aircraft is at point A on the centre line of the runway, and is heading correctly is shown in Fig.3. If the pilot now operates the controls so that the aircraft makes a flat turn to the left, he will see the runway move laterally to the right of the fixed sighting line as shown in Fig.4. In addition, the apparent shape of the runway will change slightly in that the short sides of the rectangle when produced far enough meet on the horizon.

3.2 Now imagine that there are lines on the ground parallel to the runway and extending in front of the aircraft to infinity. When the aircraft is at A, these lines would appear to the pilot to radiate from the point H where the fixed sighting line cuts the horizon, as shown in Fig.5. If the aircraft is flying on the correct compass course, but is laterally displaced to point B on the line marked "5", then the pattern seen by the pilot will be as shown in Fig.6, that is, it will appear to have rotated round H. In this case the apparent shape of the runway will have changed very considerably. It should be noted, however, that the short edges of the rectangle still appear to be horizontal.

3.3 Now if we again suppose the aircraft to be at A but to be banked instead of level, then the 5 lines shown in Fig.5, together with the horizon, will appear to have rotated about the point where the axis of roll intersects the ground. Since this point is close to H, it follows that if the horizon were missing, the pilot would have some difficulty in deciding from the ground indications whether the rotation was due to bank or to lateral error. This is exactly what happens in bad visibility when straight lines arranged in this manner are used as approach aids.

3.4 In addition to lining up on the runway, the pilot has to adjust his height so that he will touch down at the right point. This is the most difficult judgment to make, because the only indication the pilot has of his aiming point is that objects nearer to him than point P where the approach path cuts the ground appear to him to move downwards underneath the fuselage, while objects further away than P appear to move upwards towards the horizon. Point P is, of course, fixed with respect to the horizon. Of course as well as judging the aiming point, the pattern formed by the runway and horizon must be one which the pilot recognises to mean that he is at the right height to enable him to come in at his proper speed. When neither point P nor the horizon is visible, the pilot has no visual means of judging his point of touch down, unless some special approach aid is provided.

4 Low intensity approach lighting systems

4.1 If atmospheric conditions are such that lights on the ground can be seen from distances exceeding a mile or so, then any distant lights will serve to give the pilot his horizon, and approaches can be made on the runway lights alone, provided the runway can be located. In the case of aerodromes situated in built-up areas, finding the runway may be made difficult by extraneous lighting on the aerodrome itself and in the surrounding streets. Even in clear weather this difficulty may be appreciable because modern runway lights are usually designed to concentrate the light up and down the runway. These lights are dimmed in clear weather in order to obviate dazzle when landing, with the result that the intensity in directions normal to the runway is reduced to a negligible value. It has therefore been suggested that non-instrument runways should be fitted with "low intensity" approach lights covering a wide angle in azimuth, and having an intensity several times greater than the highest intensities normally found in street lighting. As these lights mark the end of the runway to be used, they may be regarded partly as a navigational aid, and partly as an approach aid.

4.2 If such lights are used, the best arrangement for them is along the extended centre line of the runway, since with this arrangement, the pilot knows he is in line with the runway when the line of approach lights appears vertical, that is, when the perspective angle is zero. (See Fig.1 for definition of "perspective angle".) If the approach lights were arranged in a line parallel with the runway, then the perspective angle would continually increase as the height of the aircraft decreased, and as the pilot has no means of knowing what this angle should be, it follows that the lights would not provide accurate alignment. Two lines of lights symmetrically disposed about the centre line form a satisfactory alignment indicator, but are no better for this purpose than a single line up the middle. It is true that the double line arrangement provides a height indication, but this by itself is of no value because what the pilot requires to know when making an approach is not his absolute height, but his height in relation to the distance from the point of touch down. This he gets very accurately from the angle of approach indicator.

4.3 A typical low intensity system is shown in Figs. 7 to 12, which are perspective diagrams showing the views as seen by the pilot of an aircraft approaching down the centre line at an approach angle of $2\frac{1}{2}^{\circ}$.* In this system, the lights are arranged in groups of three, in order to distinguish them from street lights, to give some impression of range; and to add to their effective intensity when seen from long distances. The lights forming a group are mounted on the cross-bar of a pole, 5 feet apart, the cross-bar being arranged transversely to the centre line of the runway. The projectors are parabolic troughs with sodium lamps as sources, the idea being to utilise the high efficiency of these sources as well as their distinctive colour. The projectors would give an intensity of about 8000 candles, which is about twice the highest intensity met with in street lighting. By turning the two outer projectors 45° outboard, an angle of more than 180° in azimuth could be covered.

* These diagrams are all made for a perspective distance of 10", and to get a realistic impression from them, they should be held at this distance in front of one eye, the other eye being closed.

5 Limit of usefulness of low intensity systems

5.1 The system described above will begin to be inadequate when the range of the angle of approach indicator is less than one mile, and will be of little use when the range has fallen to half a mile. However, this condition can be made to correspond with quite bad weather by using an indicator of high intensity, that is, one giving 10,000 candles or more in the red and green sectors. The range at which such an indicator could be used will be half-a-mile in a meteorological visibility of the order of 1000 yards in daytime, and of the order of 350 yards at night. In conditions worse than this, a pattern must be used which gives to the pilot the information which he previously obtained from the real horizon and the angle of approach indicator, and which obviates the ambiguity between lateral error and bank, which, as we have seen in paragraph 3.3 above, is associated with lines parallel with the runway.

6 High intensity approach lighting systems

6.1 A high intensity system may be defined as a system comprising lights of over 10,000 candle power, arranged in a pattern which enables the pilot to make an approach at night in meteorological visibilities worse than 500 yards, the aircraft being brought down to a height of 200 feet or so and fed into the lighting system by radio. As a rough guide, it can be taken that the meteorological visibility at which ranges of the order of 1000 feet are obtained from approach lights of between 10,000 and 100,000 candle power is about three times higher in daytime than at night. This means that if a high intensity system can be safely used at night down to a meteorological visibility of 200 yards, it will be useful in daytime down to a meteorological visibility of 600 yards. It is, of course, impossible to guess what this lower limit will be for civil aircraft until these systems have been in use for some time.

6.2 When visibility is near the limit at which approach lights cease to be a useful aid, only a small amount of the whole pattern will be seen by the pilot when he first picks up the lights. Fig.13 shows the part of the field of view within which the pattern will become visible at various heights when the range of the lights is 1000 feet, and it will be noted that at 200 feet, the angular distance in the ahead direction is only 3°. The central problem is how to choose a pattern which, when only a small strip of it is seen over the coaming, will convey to the pilot all the information he requires in order to make those last-second adjustments to his height and heading which will ensure that he touches down on the runway.

6.3 It would appear that the only way in which each strip of the pattern can be related to the touch down point is to derive the pattern from a vee, the apex of which is at this point. Fig.14 shows a vee pattern, and Fig.15 shows perspective views of it from three points at different heights. Any approach path such as AP, together with the lines XQ and YQ may be regarded as the edges of a tetrahedron, and the inverted vee lines shown in the perspective diagram may be regarded as its vertical cross-section. As all vertical cross-sections are similar, it follows that the angle of the vee when seen in perspective is constant for all points on any approach path passing through P.

6.4 This property of the vee pattern is the basis of the "horizon bar" pattern shown in plan in Fig.16 and in perspective in Fig.17. This consists of a line of lights along the extended centre line of the runway, with bars of lights arranged at intervals across it, the length of each bar being proportional to its distance from a certain selected point on the runway. This would normally be the point where the radio glide path intersects the runway. When an aircraft is making an approach down a path intersecting the runway at the selected point, then each bar, as it disappears underneath the coaming, will subtend the same angle at the pilot's eye. If succeeding bars appear to decrease in length, the aircraft is overshooting the selected point, and if they increase, the aircraft is undershooting. The pilot's task, then, is to note the length of the first bar which he sees, and then to fly so as to keep the next bar about the same length. It should be particularly noted that the pilot is not tied to an ideal approach path fixed in space.

6.5 An important advantage of this pattern is that it resolves the confusion between lateral error and bank to which attention was drawn in paragraph 3.3 above. This is due to the fact that the transverse lines only appear to rotate appreciably when the aircraft banks. However large the errors in position, the bars always remain horizontal. The distinction is made clear in the diagrams shown in Figs.18 and 19.

6.6 Since the height indication is by a change in apparent length of the bars, and since this is proportional to the change in the perspective angle of the vee, the sensitivity of the indication will be maximum when the rate of change of the perspective angle is maximum. It can easily be shown, (see para. 7 below), that the rate of change of the perspective angle is maximum when the approach is made at an angle equal to half the actual angle of the vee. Since the radio approach angle is about $2\frac{1}{2}^{\circ}$, it follows that 5° is a suitable angle for the vee.

6.7 Now if the bar consisted of lights spaced, say, 3 feet apart, then the power consumption would be large, and wayleaves would cause difficulty. If, however, the bar is made up of groups of lights as shown in Fig.20, not only is power saved, but an indication of range can be given. This is achieved by dividing the bar into four equal parts, two of which are AC and CD. If the bar is then imagined to represent the approach path, and if A is taken to represent the beginning of the approach, and C the beginning of the runway, then the length of the string of lights AB can be taken to represent the length of the approach path which has been traversed. Alternatively if some standard length of approach path is agreed upon internationally as being represented by AC, then the first bar of a system which was half the standard length could be made as shown in Fig.20.

6.8 As this pattern is very distinctive, colour is not necessary in order to differentiate it from street lights and other disturbing patterns. It is proposed, however, that the lights along the centre line should be yellow, so as to conform with the low intensity pattern described under paragraph 4 above. The low intensity pattern can then be converted into a high intensity pattern by merely adding the bars, and possibly changing the fittings.

7 Runway Lighting

7.1 If the pilot has been able to use the approach aids successfully, the aircraft should arrive over the end of the runway at a height such that the pilot's head is about 50 feet above the ground. After the end of the runway has been crossed, the pilot has no further need to relate his height to any particular point of touch down, and a pattern which merely indicates height and direction, and perhaps horizon, is sufficient. A pair of parallel lines will, of course, indicate height and direction by means of the change in the perspective angle θ. Figs.21 and 22 show how the accuracy of this indication varies with height "h" for various spacings "2w" between the lines. These curves are obtained as follows:-

$$\theta = \tan^{-1} w/h$$

$$\therefore \frac{d\theta}{dw} = \frac{h}{w^2 + h^2},$$ giving the family of curves shown on Fig.21,

and $$\frac{d\theta}{dh} = -\frac{w}{w^2 + h^2},$$ giving the family of curves shown on Fig.22.

7.2 Some valuable results can be obtained from an inspection of these formulae and the curves, and among these attention is drawn to the following:-

(a) When h is large compared with w, lateral error is indicated with an accuracy proportional to $1/h$, and height with an accuracy proportional to w/h^2.

(b) When h is small compared with w, lateral error is indicated with an accuracy proportional to h/w^2, and height with an accuracy proportional to $1/w$. (This is the case which is important for taxying.)

(c) If the most accurate indication of height is required at a particular height "h", then the spacing should be 2h.

(d) The height at which a pair of lines spaced at 2w gives the most accurate indication of lateral error is equal to w.

7.3 Of these results, perhaps (b) is the most important because it shows that the difficulty of judging direction from the runway lights when touching down varies directly as the square of the distance between the rows, and inversely as the height of the pilot's head. The pilot of a small aircraft landing on a wide runway will therefore receive very poor indications of direction from the runway lights, and as in poor visibility all other indications are blotted out, there will be a considerable danger of swinging off the runway. The reason why this is not generally realised is that in clear weather one gets about the world by choosing a succession of aiming points, not by following lines. In poor visibility, however, these aiming points are blotted out, near objects become important, and one is reduced to "kerb crawling".

8 Scale effects in runway lighting

8.1 Now a pilot is only able to judge his height from a pair of parallel lines provided he is familiar with the scale of the pattern. To take two actual cases, if in country A, the distance between the rows is 200 feet, and the distance between lights 100 feet, and if in country B, the corresponding distances are 150 feet and 75 feet, then the runway in country B is a scale model of that in country A, the scale being 1 to 0.75. The runway pattern in country A, seen from any height "h" will therefore be identical with the pattern seen in country B from a height of 0.75 h. It follows that unless the pilot can remember which pattern he is landing on, his judgment of height will be in error by 0.25 h.

8.2 There would seem to be only two ways of meeting this difficulty. One is to standardise a particular pattern internationally, and call on each country to adopt it on international airports. The other is to call on each country to add a scale-fixing pattern to the existing pattern, this pattern to extend for an agreed distance on either side of the selected touch down point. This pattern could take the form of transverse bars, or longitudinal lines, but whatever pattern is chosen, it must be completely specified. This arrangement may, for convenience, be called a "contact mat". The writer is of the opinion that longitudinal lines are preferable because of the increased accuracy of the indications obtained at low heights. Fig.23 shows the principle of the contact mat applied to an existing British runway, and Fig.24 is a perspective diagram of this mat as seen from a point 25 feet vertically over the centre line.

8.3 The writer is well aware of the fact that the installation of a contact mat necessitates the use of flush type lights, and that this type of light cannot be designed to give as high an intensity as the elevated type. An examination of Fig.24 shows, however, that when the distance between rows is large compared with the height of the observer, then the range of the lights must increase in proportion to the distance between rows in order to give equally good indications. In bad visibility the range of a light soon ceases to increase appreciably with increase in intensity, from which it follows that edge type lights will fail to give satisfactory indications when the width of the runway exceeds a certain value. This value the writer believes to be about 150 feet, which is the standard width used throughout this country. The intensities which have already been obtained from flush type lights, i.e. up to about 5000 candles, are sufficient for the purpose of the contact mat.

9 Concluding remarks

9.1 It is again emphasised that this report is merely an interim report on an unfinished piece of work, and that it has only been released at this stage firstly because it may stimulate discussion, and secondly because it points the way to further experiments which, it is hoped, will provide a solution to this problem, the urgency of which has been demonstrated by the accidents which have marred the history of international civil aviation during the current winter.

Attached:-				
	Fig.1	-	Drg.No.	EL.15265
	Figs.2 to 6	-	" "	EL.15269
	" 7 & 8	-	" "	EL.15270
	" 9 & 10	-	" "	EL.15271
	" 11 & 12	-	" "	EL.15272
	Fig.13	-	" "	EL.15273
	Figs.14 & 15	-	" "	EL.15274
	" 16 & 17	-	" "	EL.15275
	" 18 & 19	-	" "	EL.15276
	Fig.20	-	" "	EL.15277
	" 21	-	" "	EL.15278
	" 22	-	" "	EL.15279
	Figs.23 & 24	-	" "	EL.15280

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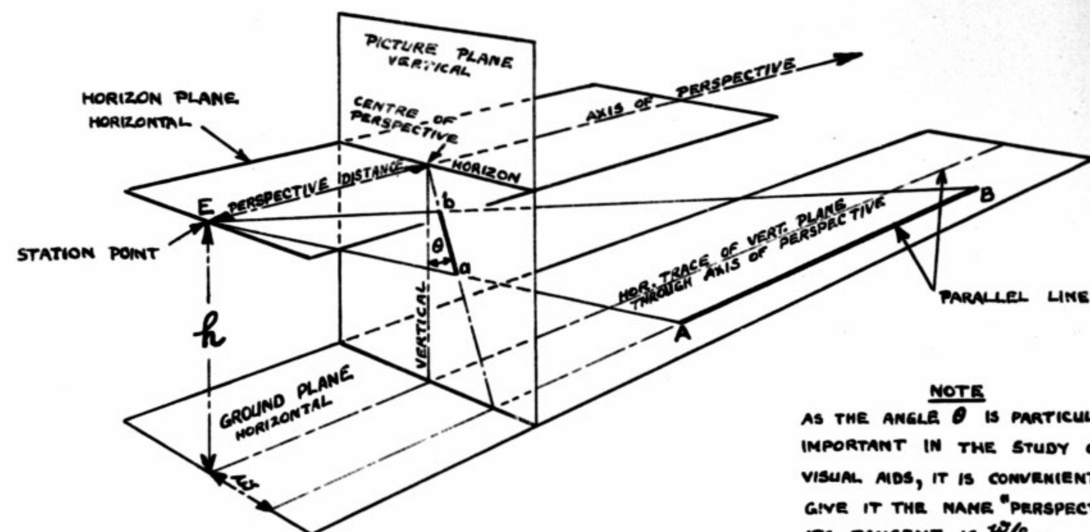
FIG. 1.



NOTE

AS THE ANGLE θ IS PARTICULARLY IMPORTANT IN THE STUDY OF THE VISUAL AIDS, IT IS CONVENIENT TO GIVE IT THE NAME "PERSPECTIVE ANGLE". ITS TANGENT IS w/h.

FIG. 1. DIAGRAM SHOWING PLANES USED IN PERSPECTIVE PROJECTION.

PERSPECTIVE PROJECTION OF AB IS ab.

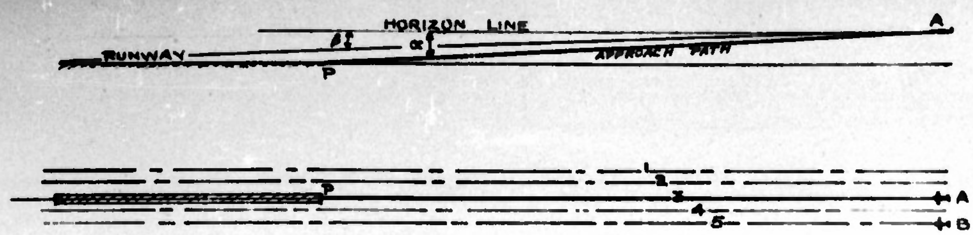


FIG. 2. PLAN & ELEVATION SHOWING AIRCRAFT APPROACHING RUNWAY

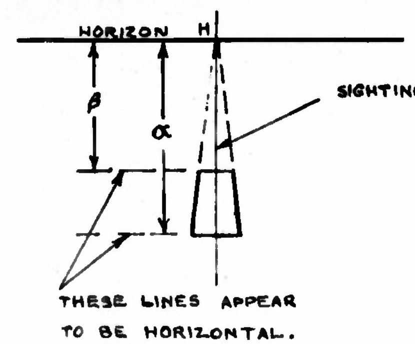


FIG. 3. VIEW FROM POSITION A.
CORRECT HEADING, NO BANK.

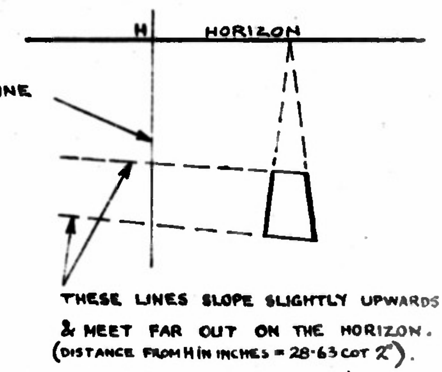


FIG. 4. VIEW FROM POSITION A.
AIRCRAFT HEADING 2° TO LEFT, NO BANK.

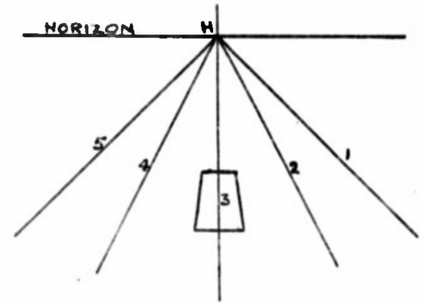


FIG. 5. VIEW FROM POSITION A.
CORRECT HEADING, NO BANK.

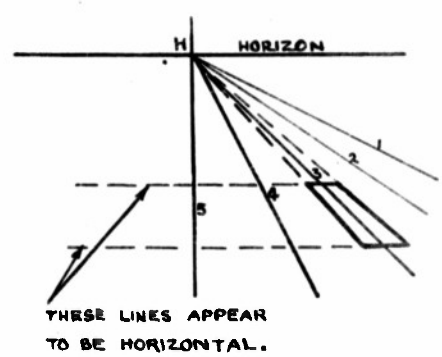


FIG. 6. VIEW FROM POSITION B.
CORRECT HEADING, NO BANK.

DIAGRAMS SHOWING APPEARANCE OF RUNWAY.

SCALE FOR FIGS. 3 TO 6 :- 1" = 2°

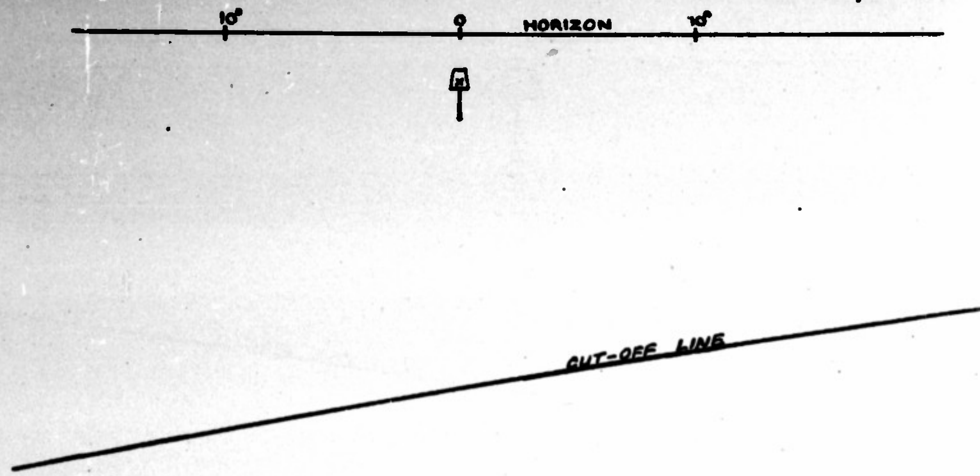


FIG. 7. VIEW FROM 500 FT., (11,500' FROM TOUCH).

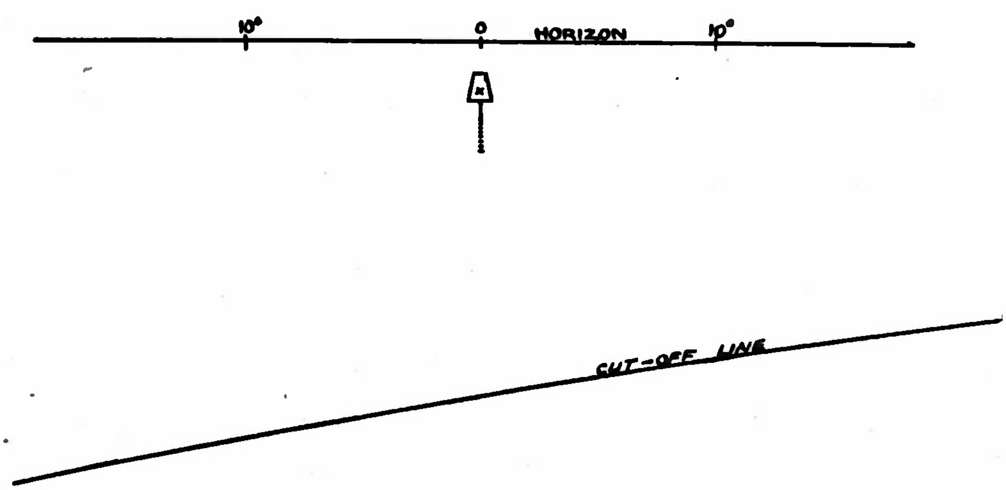


FIG. 8. VIEW FROM 400 FT., (9200' FROM TOUCH).

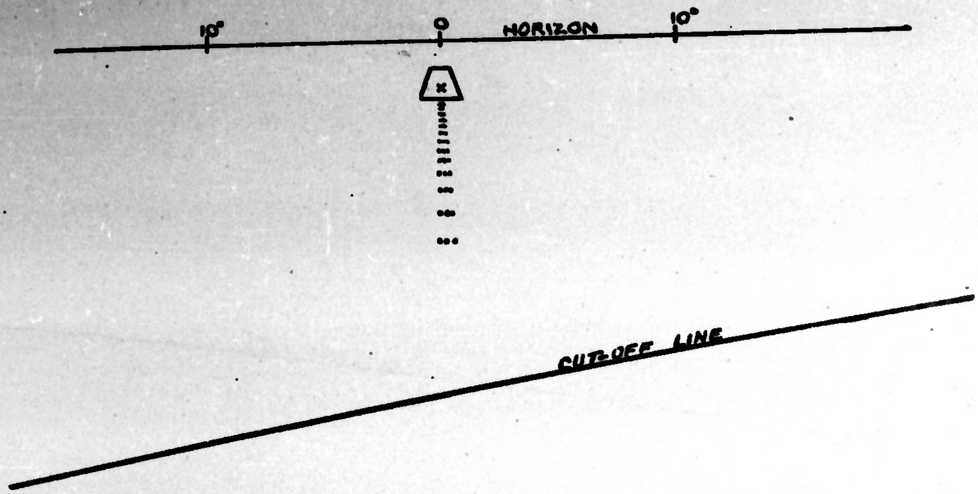


FIG. 9. VIEW FROM 300', (6900' FROM TOUCH).

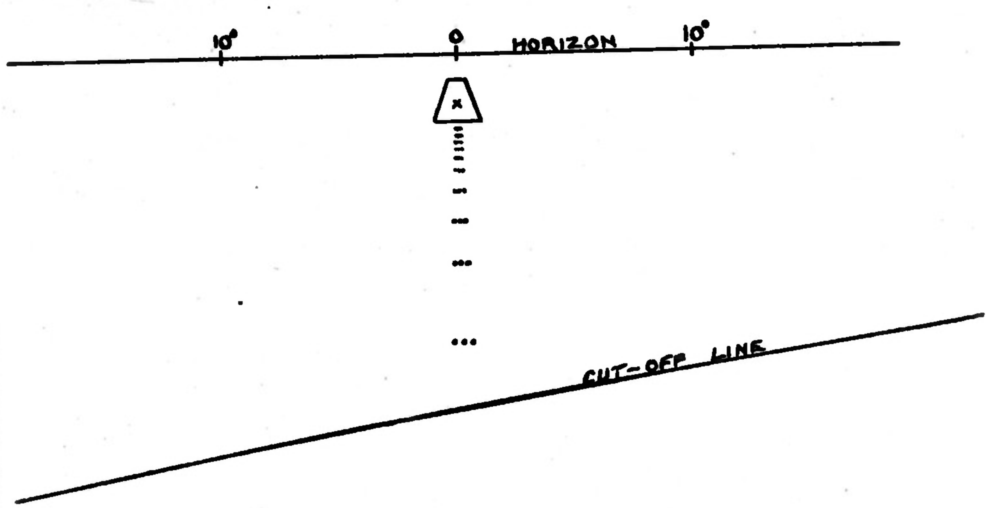


FIG. 10. VIEW FROM 200', (4600' FROM TOUCH).

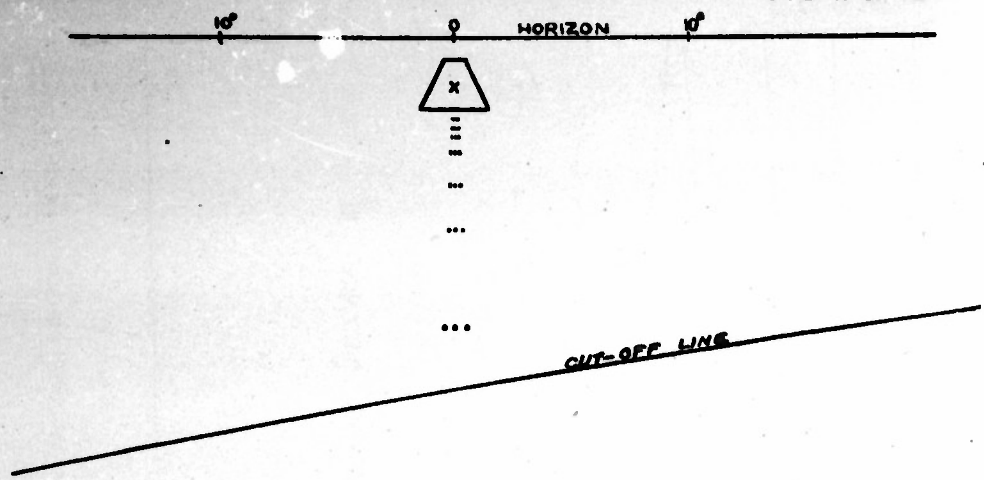


FIG. 11. VIEW FROM 150', (3450' FROM TOUCH).

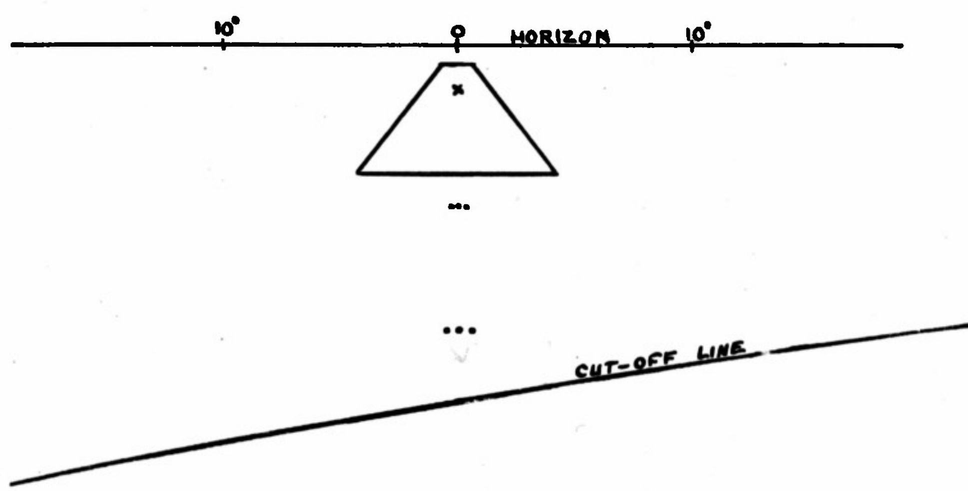


FIG. 12. VIEW FROM 100', (2300' FROM TOUCH).

FIG. 13.

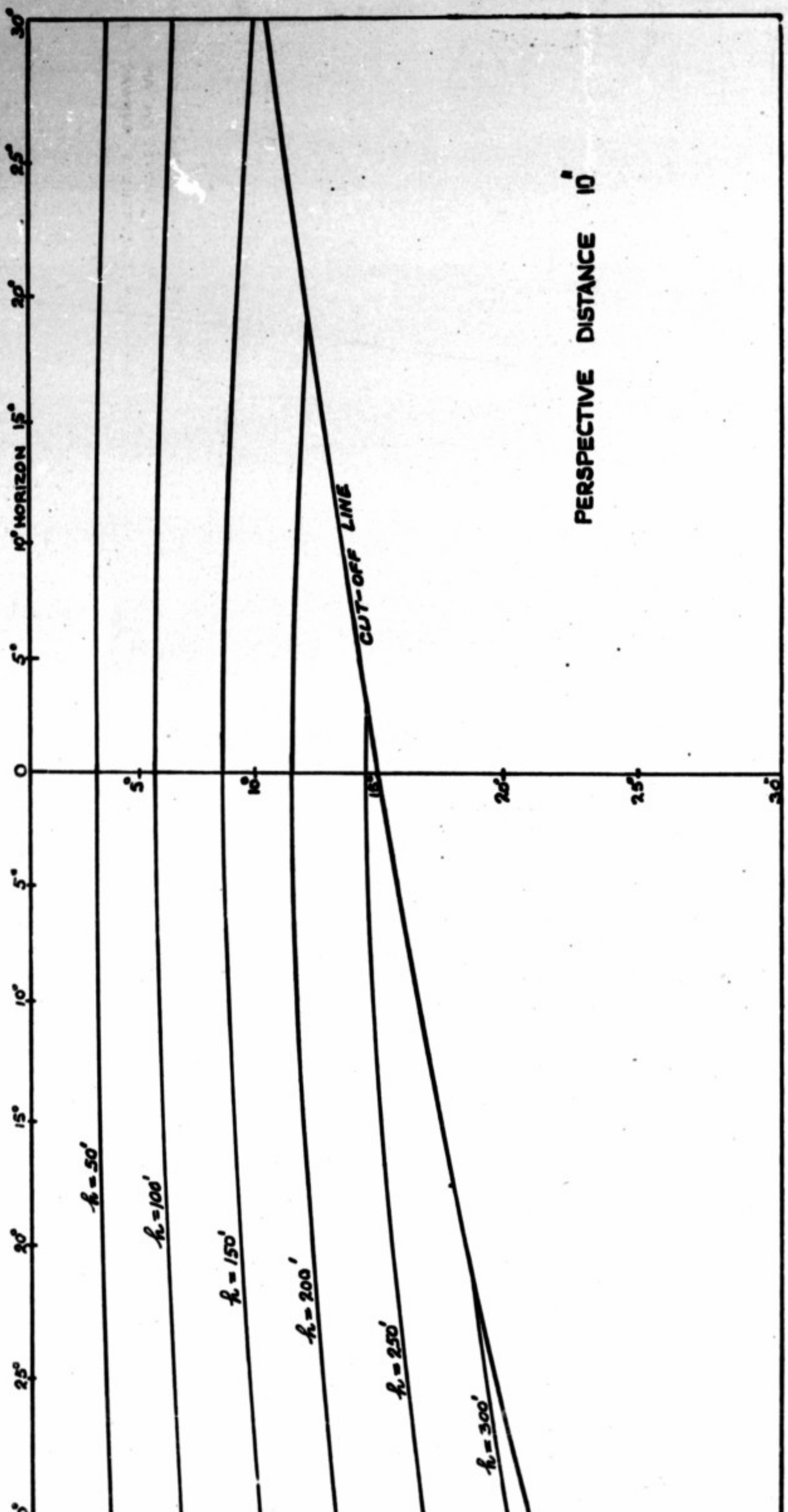


FIG. 13. PERSPECTIVE DIAGRAM SHOWING CURVES OF CONSTANT RANGE (1000') FOR VARIOUS AIRCRAFT HEIGHTS "h".

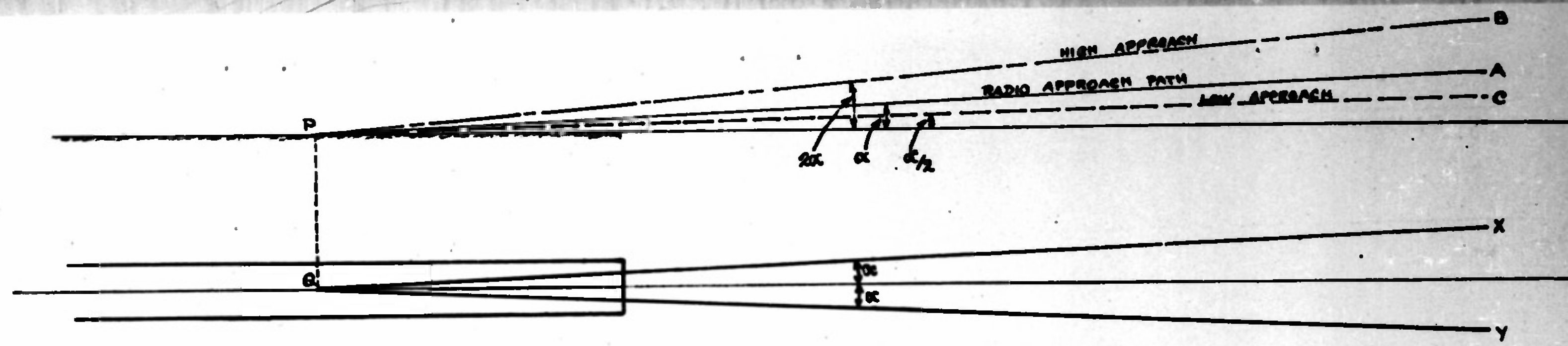


FIG.14. PLAN & ELEVATION OF APPROACHES MADE OVER CONVERGING LINES XQ & YQ.

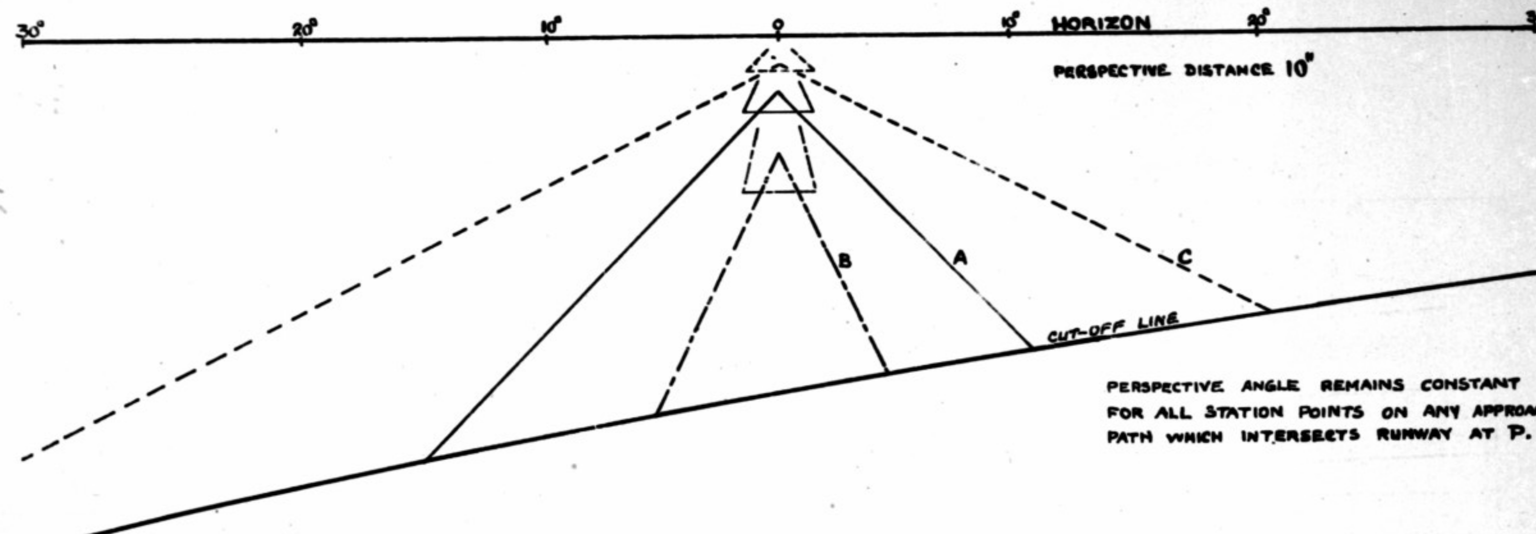


FIG.15. PERSPECTIVE DIAGRAM SHOWING LINES XQ & YQ FROM STATION POINTS A, B, & C VERTICALLY OVER ℄.

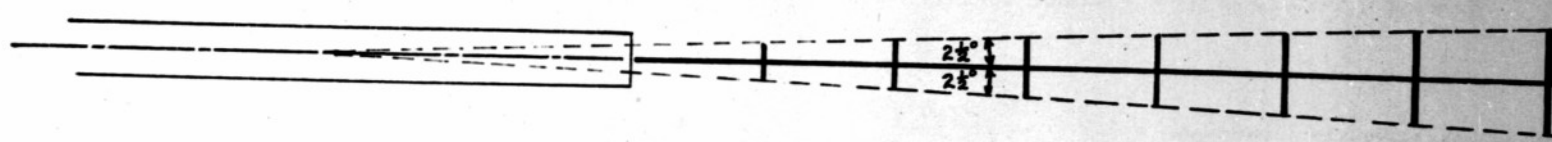


FIG. 16. SCHEMATIC DIAGRAM SHOWING PLAN VIEW OF PATTERN PROPOSED FOR HIGH INTENSITY APPROACH LIGHTS.

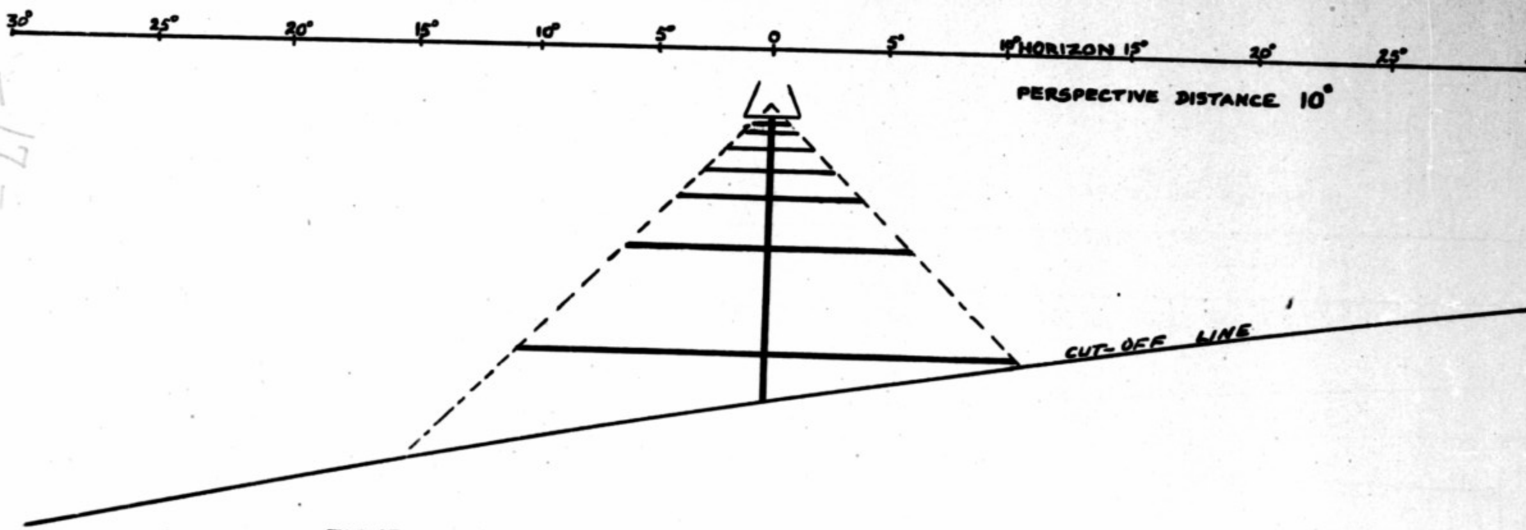


FIG. 17. PERSPECTIVE DIAGRAM OF PATTERN SHOWN IN FIG. 16.
STATION POINT VERTICALLY OVER ℄ ON 2½° APPROACH PATH.

EL. 15276

PERSPECTIVE DISTANCE 10"

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FIG. 18 & 19

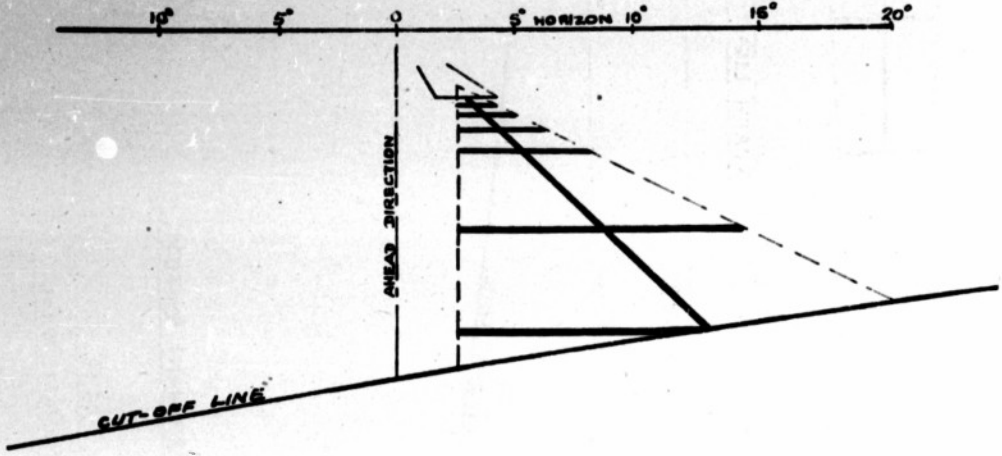

FIG. 18. PATTERN SEEN FROM STATION POINT TO LEFT OF ℄.
APPROACH ANGLE 2½°.
LATERAL ERROR EQUAL TO HEIGHT.
AIRCRAFT HEADING PARALLEL TO RUNWAY.

HORIZON OMITTED TO SHOW THAT BANK IS OBVIOUS WITHOUT IT.

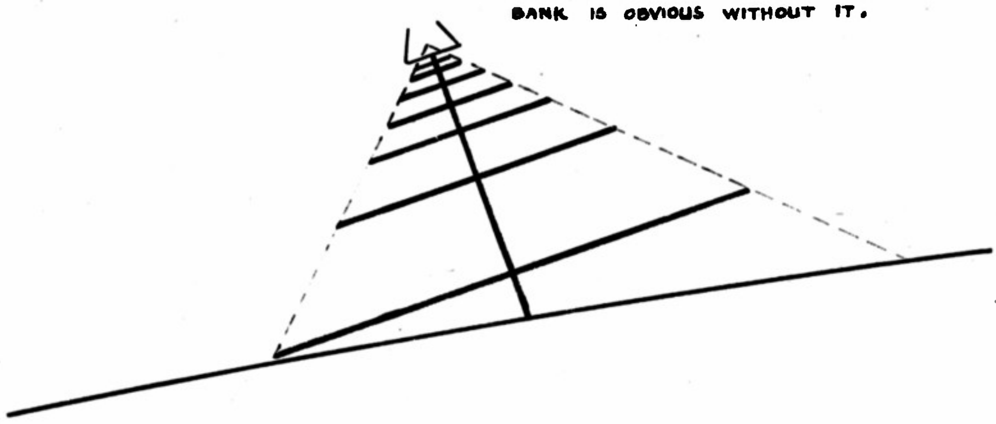

FIG. 19. PATTERN SEEN FROM STATION POINT ON 2½° APPROACH PATH.
STATION POINT VERTICALLY OVER ℄.
20° BANK, RIGHT WING DOWN.

FIG. 20

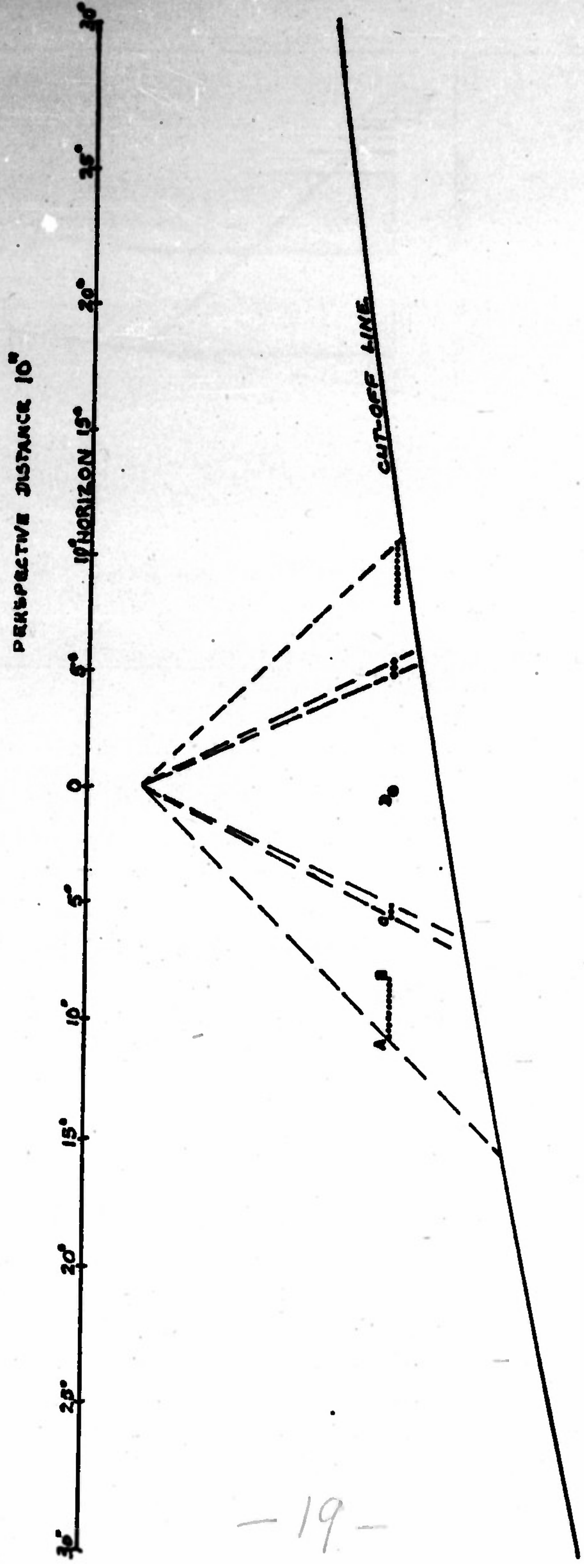

FIG. 20. PERSPECTIVE DIAGRAM SHOWING MIDDLE BAR OF APPROACH SYSTEM.

FIG.21

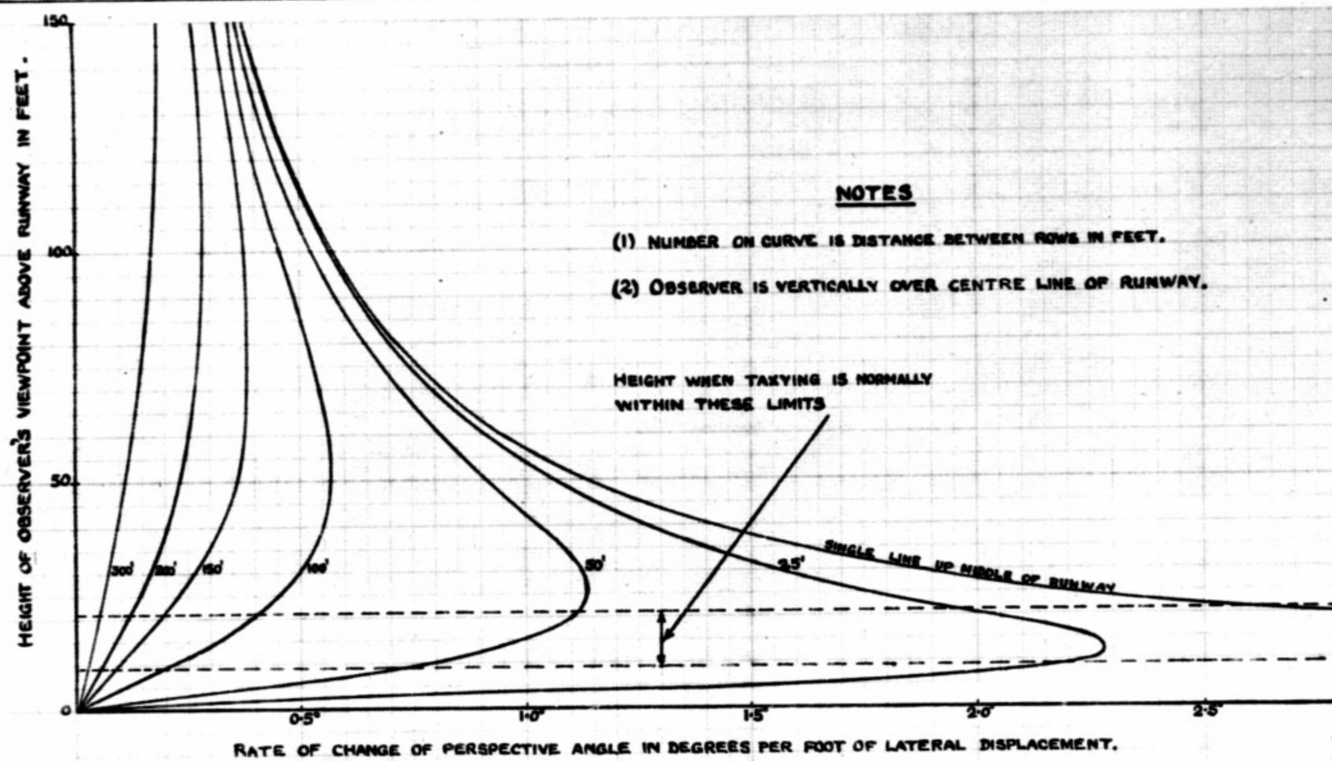

FIG.21. CURVES SHOWING THE ACCURACY WITH WHICH LATERAL DISPLACEMENT CAN BE JUDGED FROM PARALLEL ROWS OF RUNWAY LIGHTS FOR VARIOUS SPACINGS BETWEEN ROWS.

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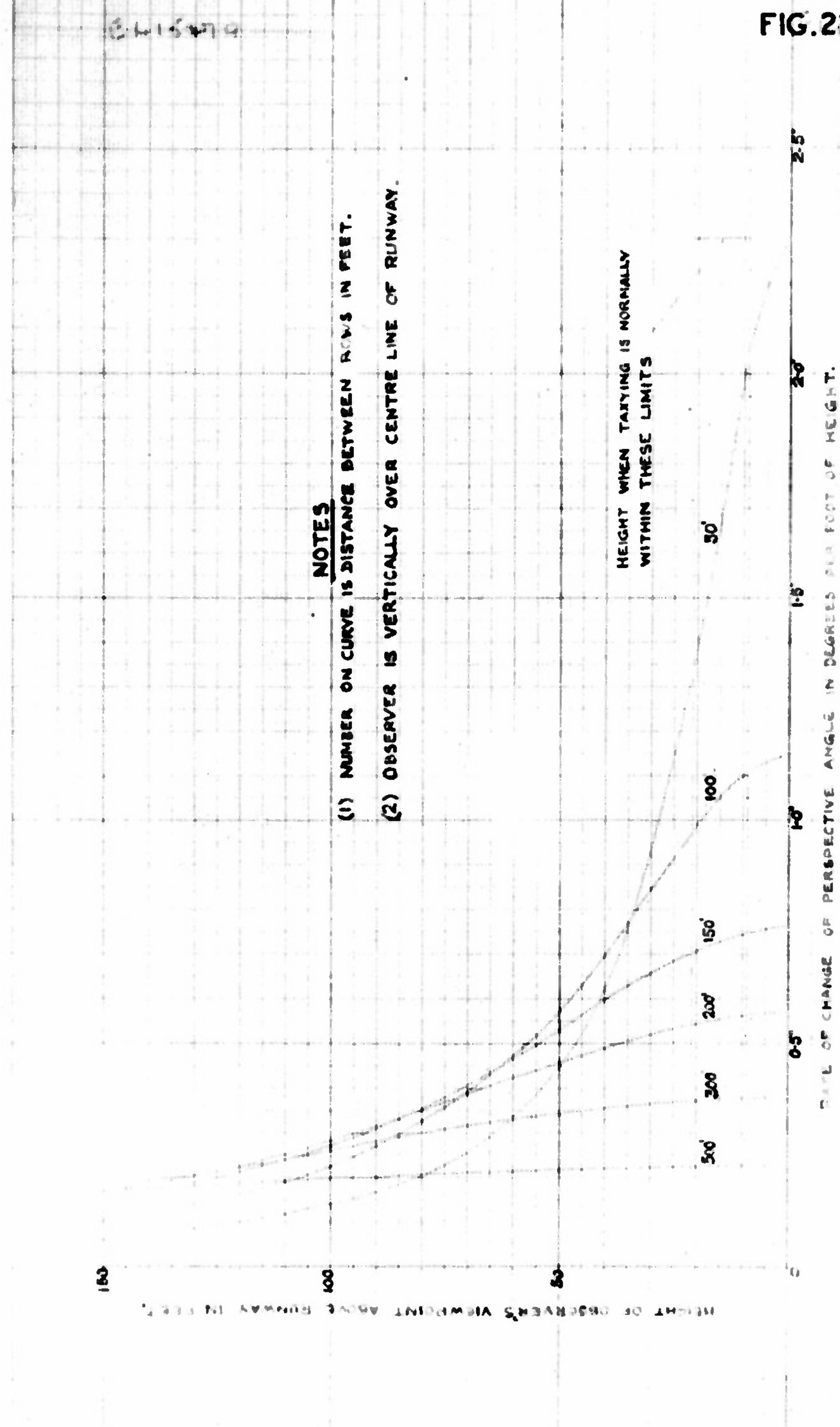
REPORT EL.1414

FIG.22



F... CURVES SHOWING THE ACCURACY WITH WHICH HEIGHT CAN BE JUDGED FROM PARALLEL ROWS OF RUNWAY LIGHTS FOR VARIOUS SPACINGS BETWEEN ROWS.

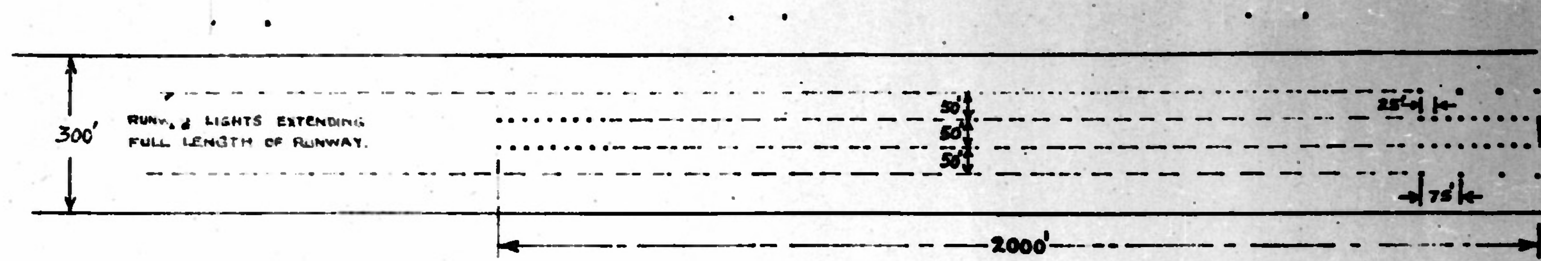


FIG.23. CONTACT MAT APPLIED TO EXISTING BRITISH RUNWAY

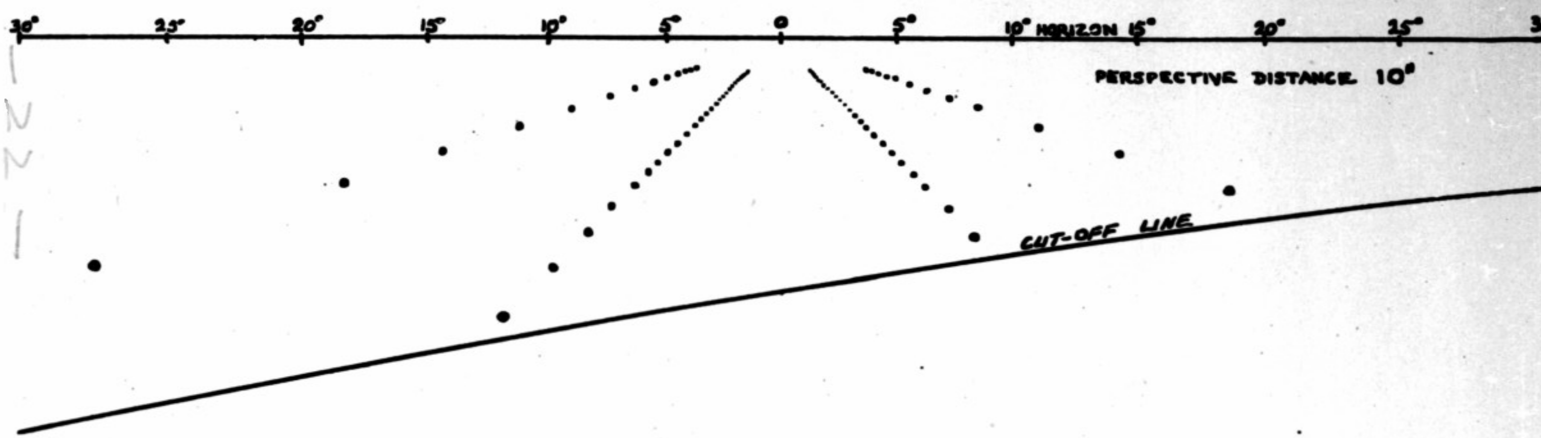


FIG.24. PERSPECTIVE DIAGRAM OF MAT SHOWN IN FIG.23.

STATION POINT 25' ABOVE ℄.

LIGHTS VISIBLE FOR 1000'.

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RESTRICTED

TITLE: Visual Approach and Landing Aids for Aircraft - Fundamental Problems Analysed by Means of Perspective Diagrams

AUTHOR(S) : Calvert, E. S.

ORIG. AGENCY : Royal Aircraft Establishment, Farnborough, Hants

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DIVISION: Airports and Airways (39)
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